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Shimizu

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(54) **LIQUID EJECTING HEAD FOR EFFECTIVELY DISCHARGING AIR BUBBLES**

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(30) **Foreign Application Priority Data**

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B41J 2/45 (2006.01)
B41J 2/18 (2006.01)

(52) **U.S. Cl.** **347/92**; 347/71; 347/89

(58) **Field of Classification Search** 347/71
See application file for complete search history.

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(57) **ABSTRACT**

A head for ejecting a liquid from ejection holes, including: a first flow-passage member in which are formed (a) a liquid-supply passage, (b) branch passages connected to the liquid-supply passage, and (c) discharge passages each being connected to any of the branch passages; a second flow-passage member in which are formed (a) at least one common passage each communicating with at least one of the branch passages and (b) individual passages having respective pressure chambers, each individual passage being connected to any one of the at least one common passage and introducing the liquid to a corresponding one of the ejection holes via a corresponding one of the pressure chambers; a first filter disposed in the liquid-supply passage; second filters disposed between the branch passages and the at least one common passage: and at least one energy giving member for giving ejection energy to the liquid in each pressure chamber.

19 Claims, 10 Drawing Sheets

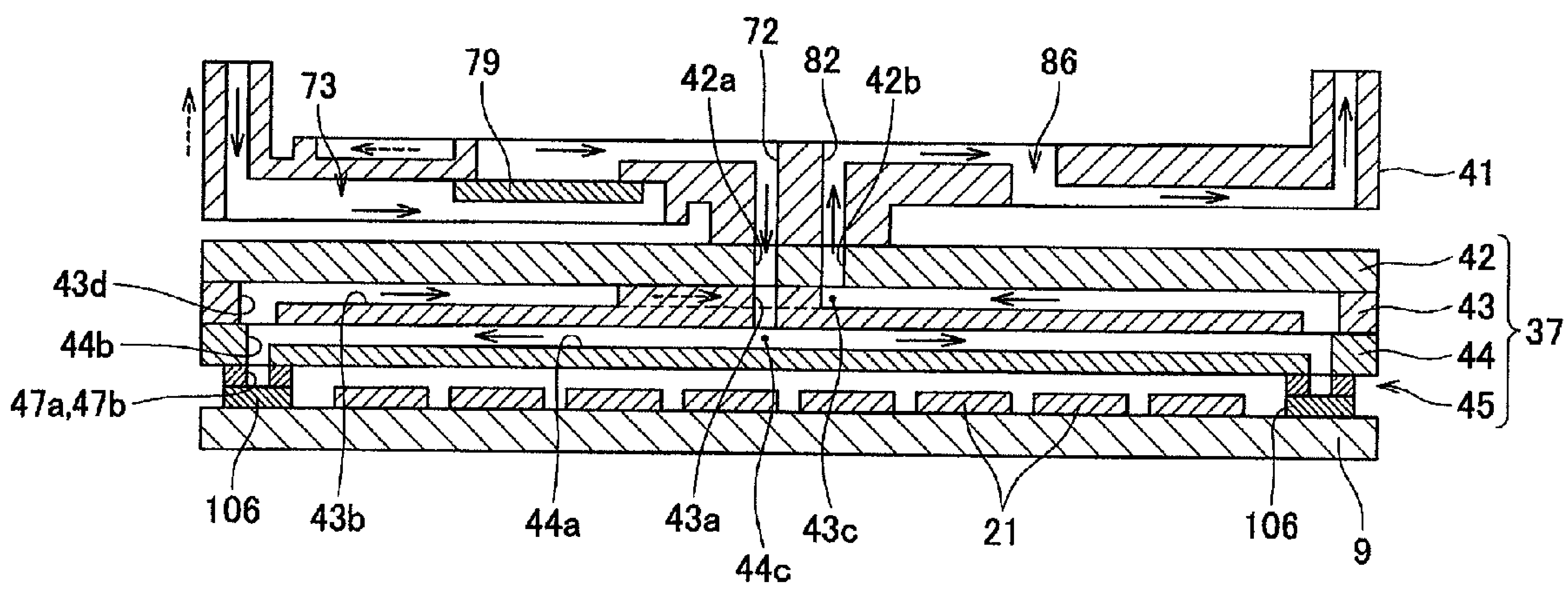
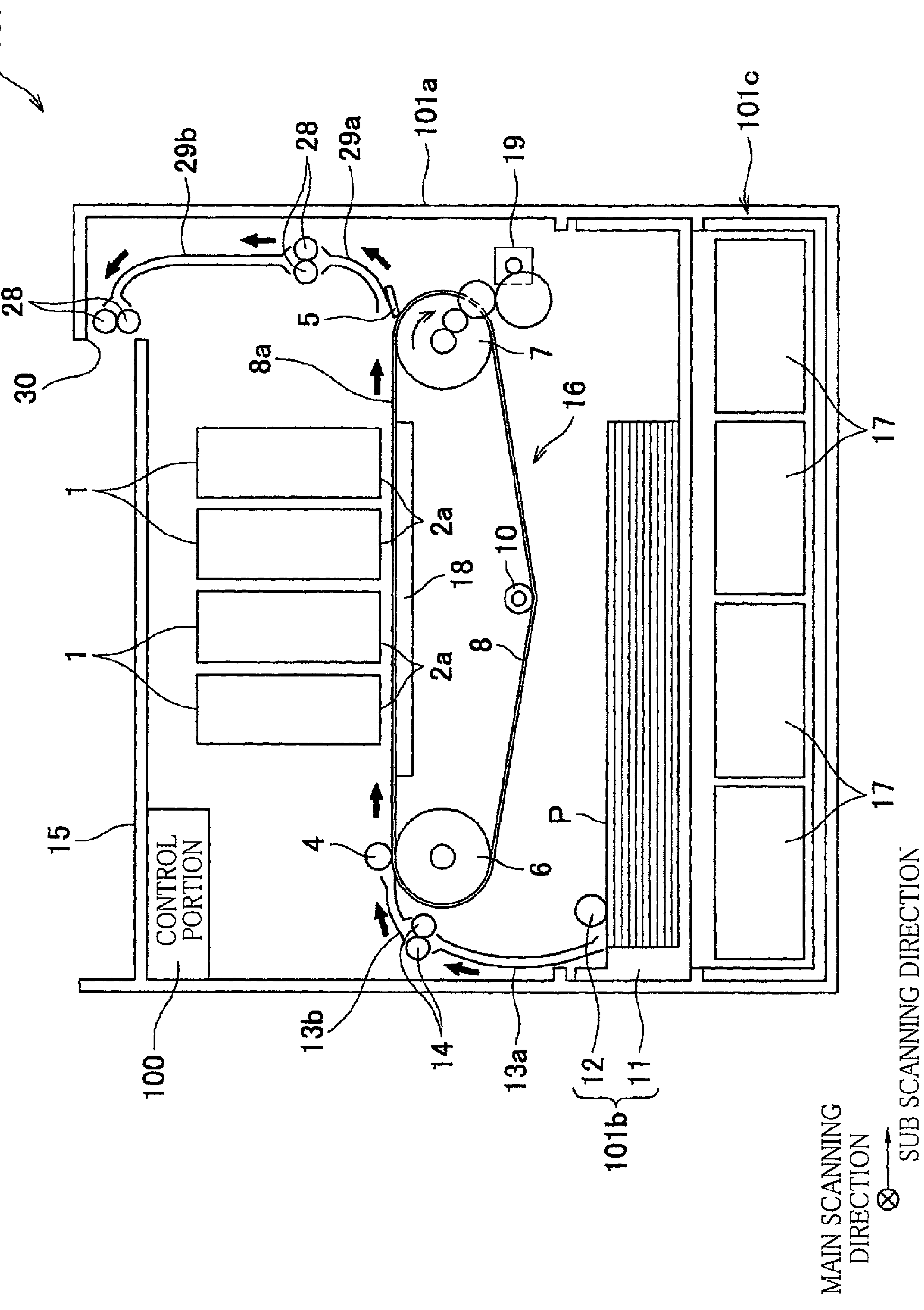


FIG.1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101a
101b
101c
100
CONTROL PORTION
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2a
4
5
6
7
8
8a
10
11
12
13a
13b
14
15
16
17
18
19
28
29a
29b
30
P
MAIN SCANNING DIRECTION
SUB SCANNING DIRECTION

FIG.2

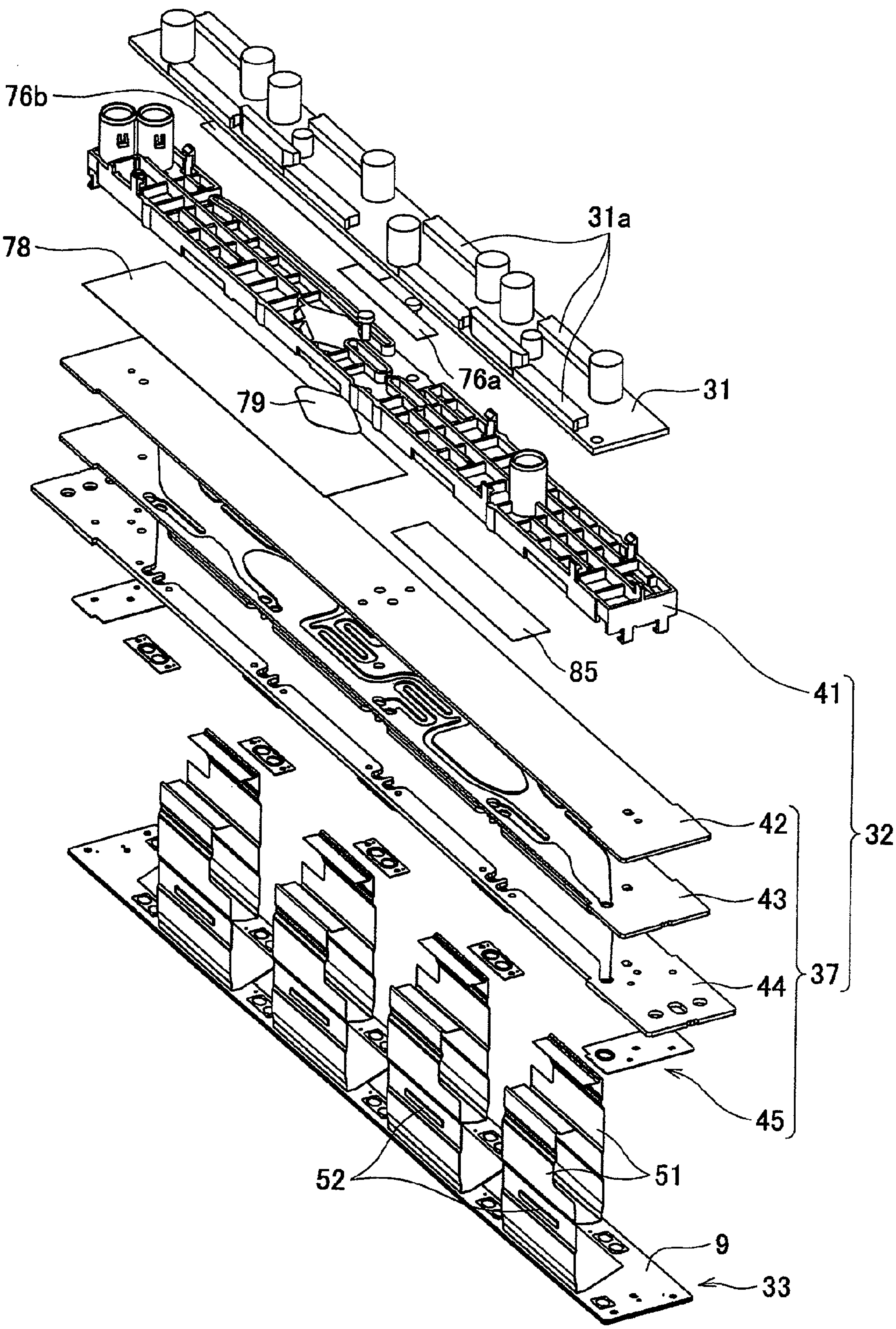
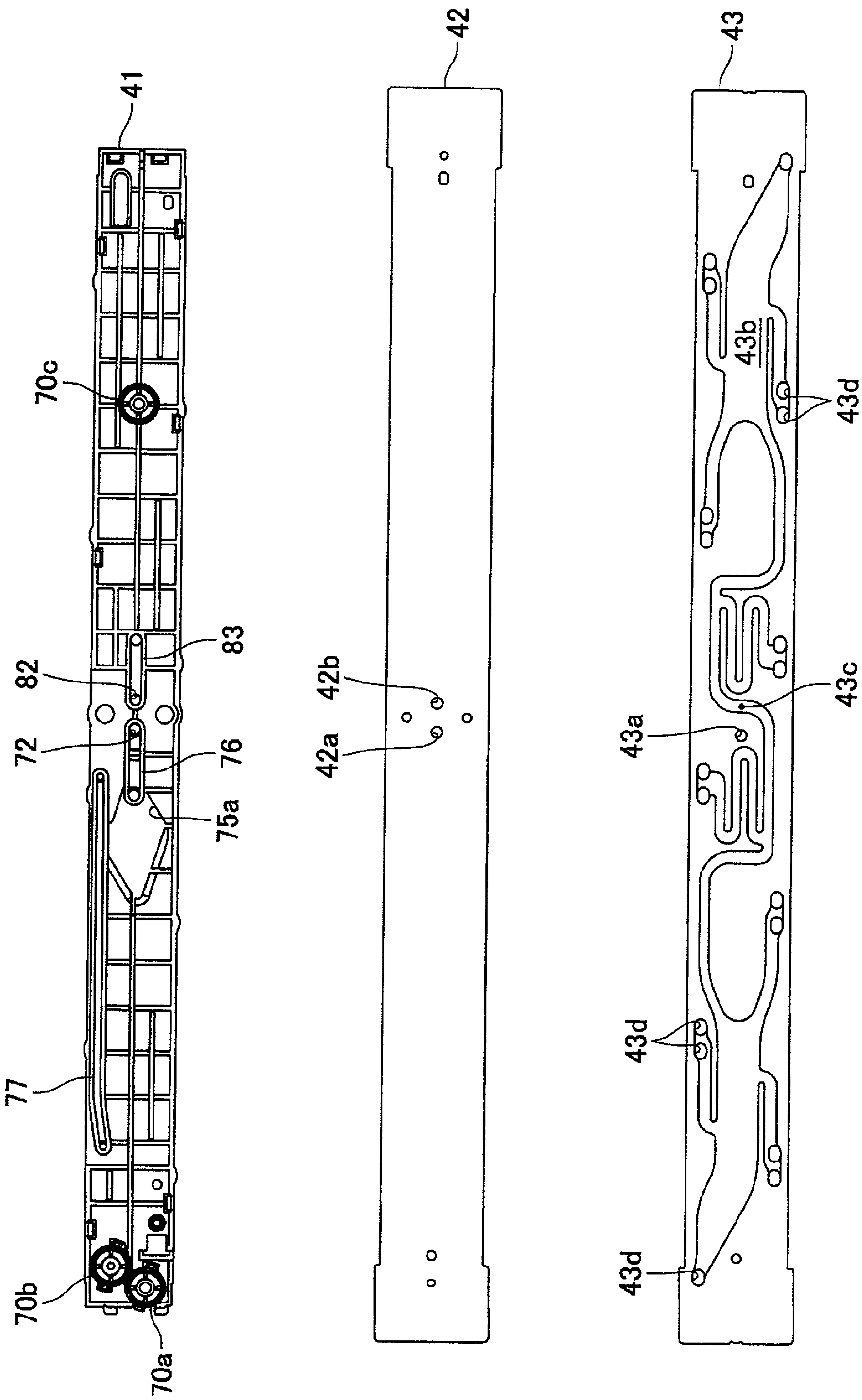


FIG.3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70c
82
83
72
76
75a
77
70b
70a
42
42b
42a
43
43b
43d
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43a
43d
43d

FIG. 4

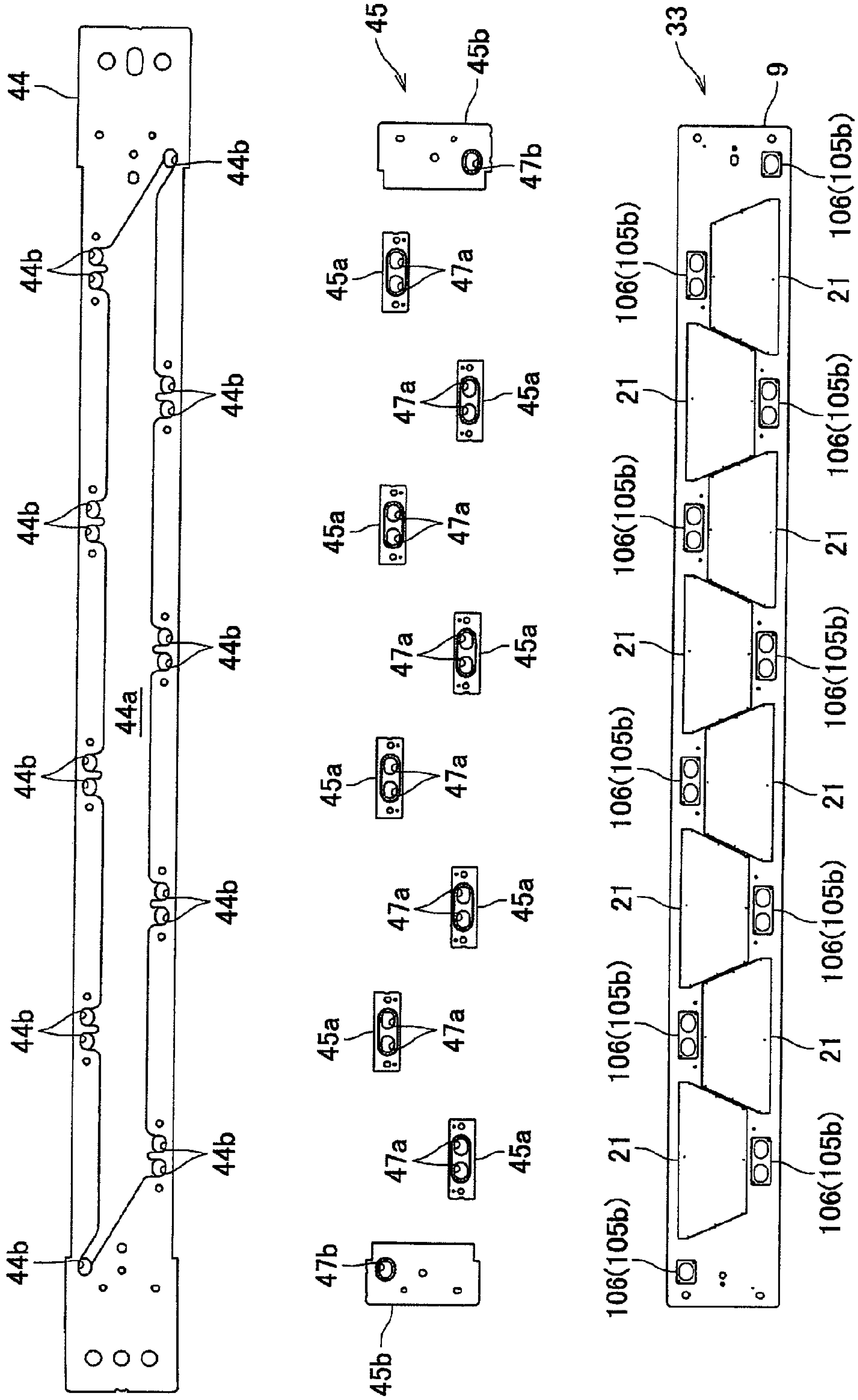
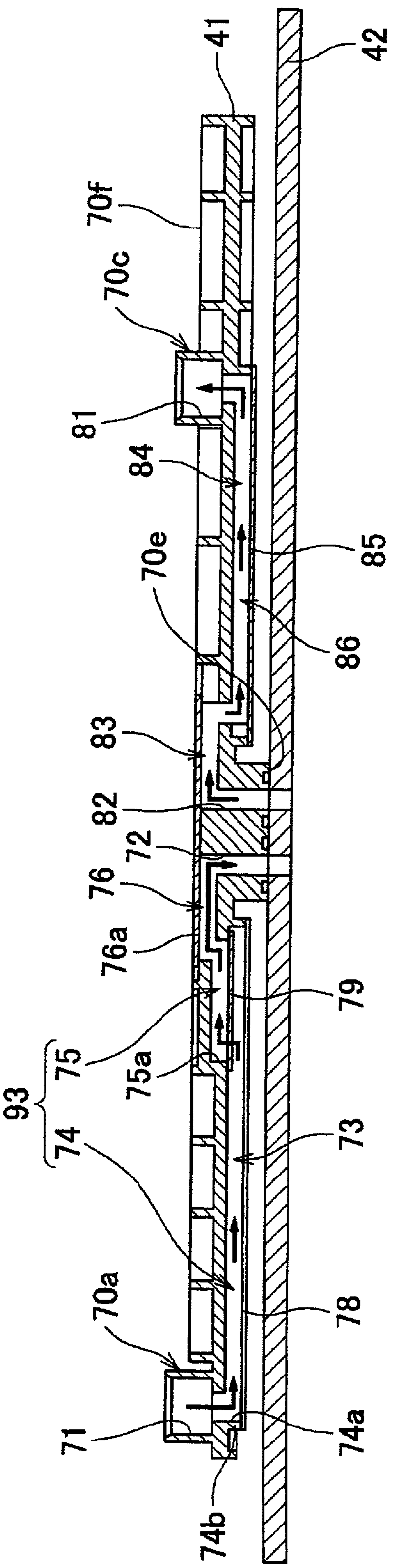


FIG.5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70c
81
84
85
70e
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83
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76a
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75a
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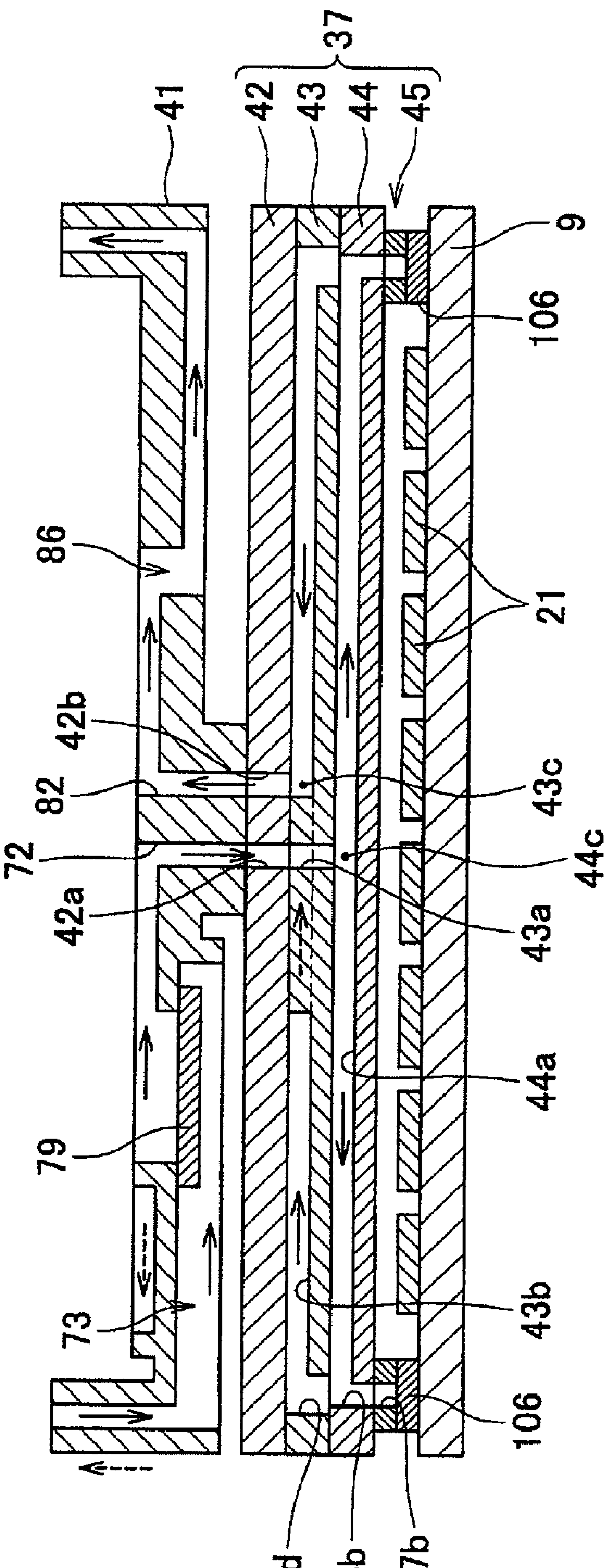
74
73
70a
78
71
74a
74b

FIG.6



37
41
42
43
44
45
9
106
86
21
42b
82
43c
72
44c
42a
43a
44a
79
73
43b
106
43d
44b
47a,47b

FIG.7

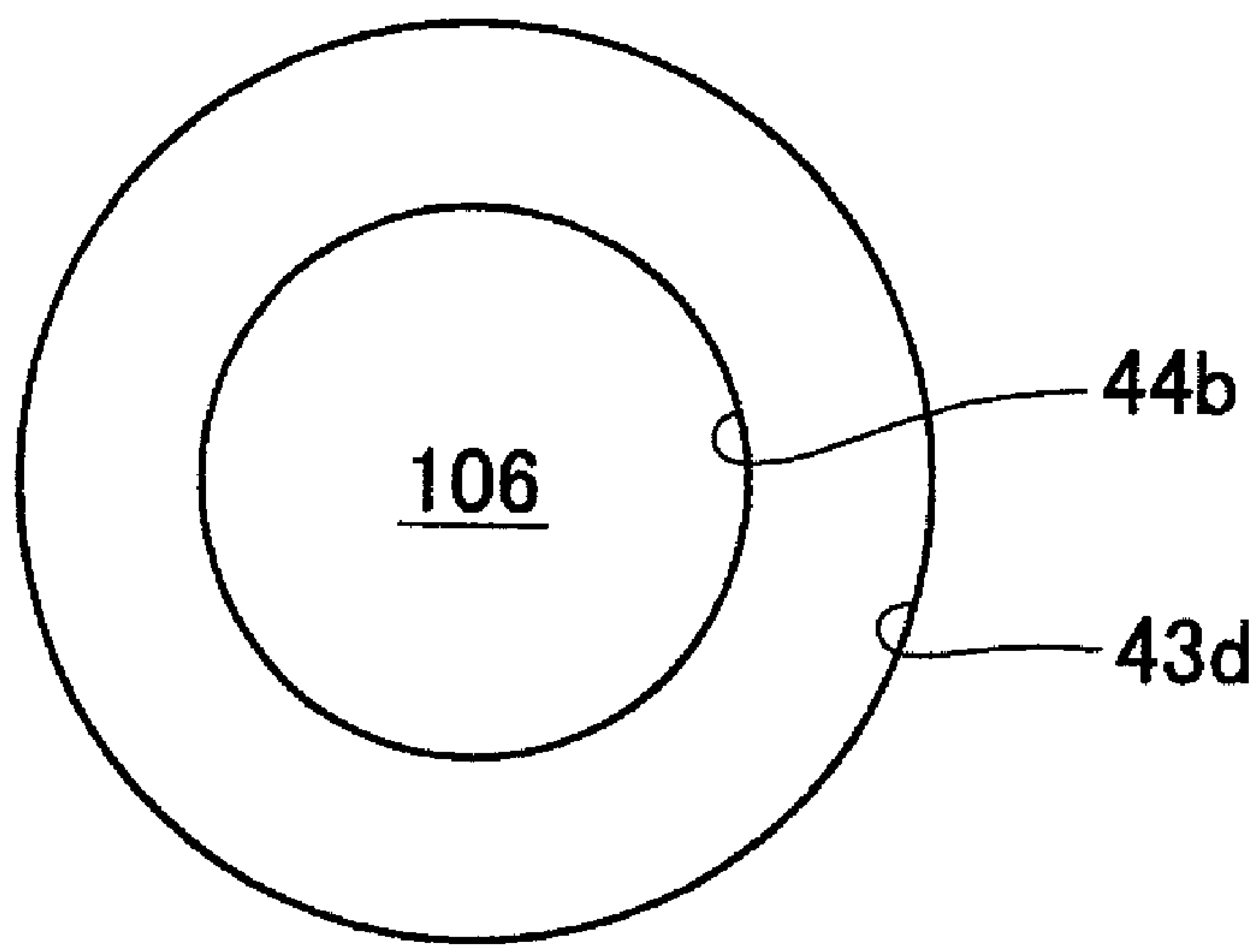


FIG.8

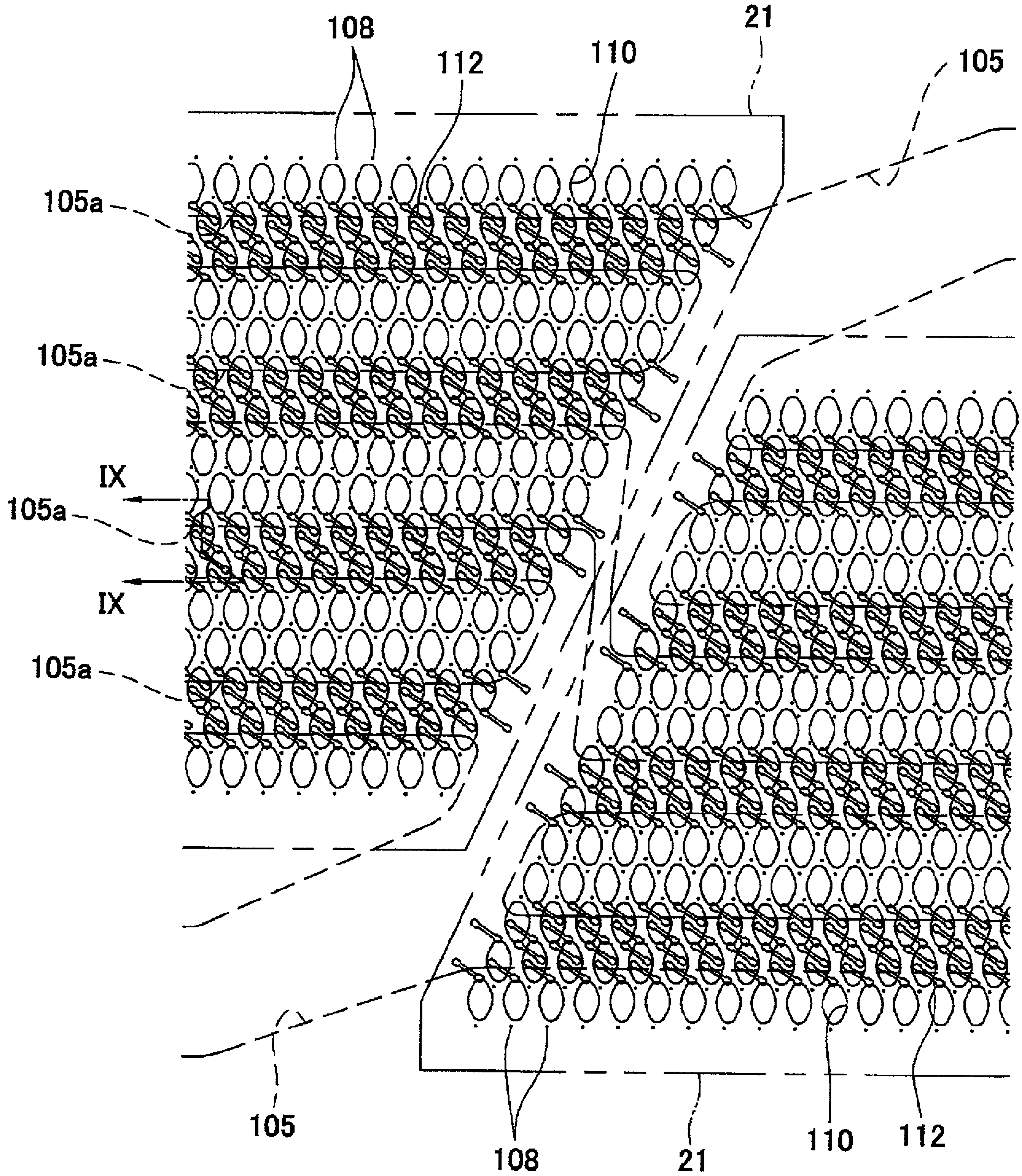
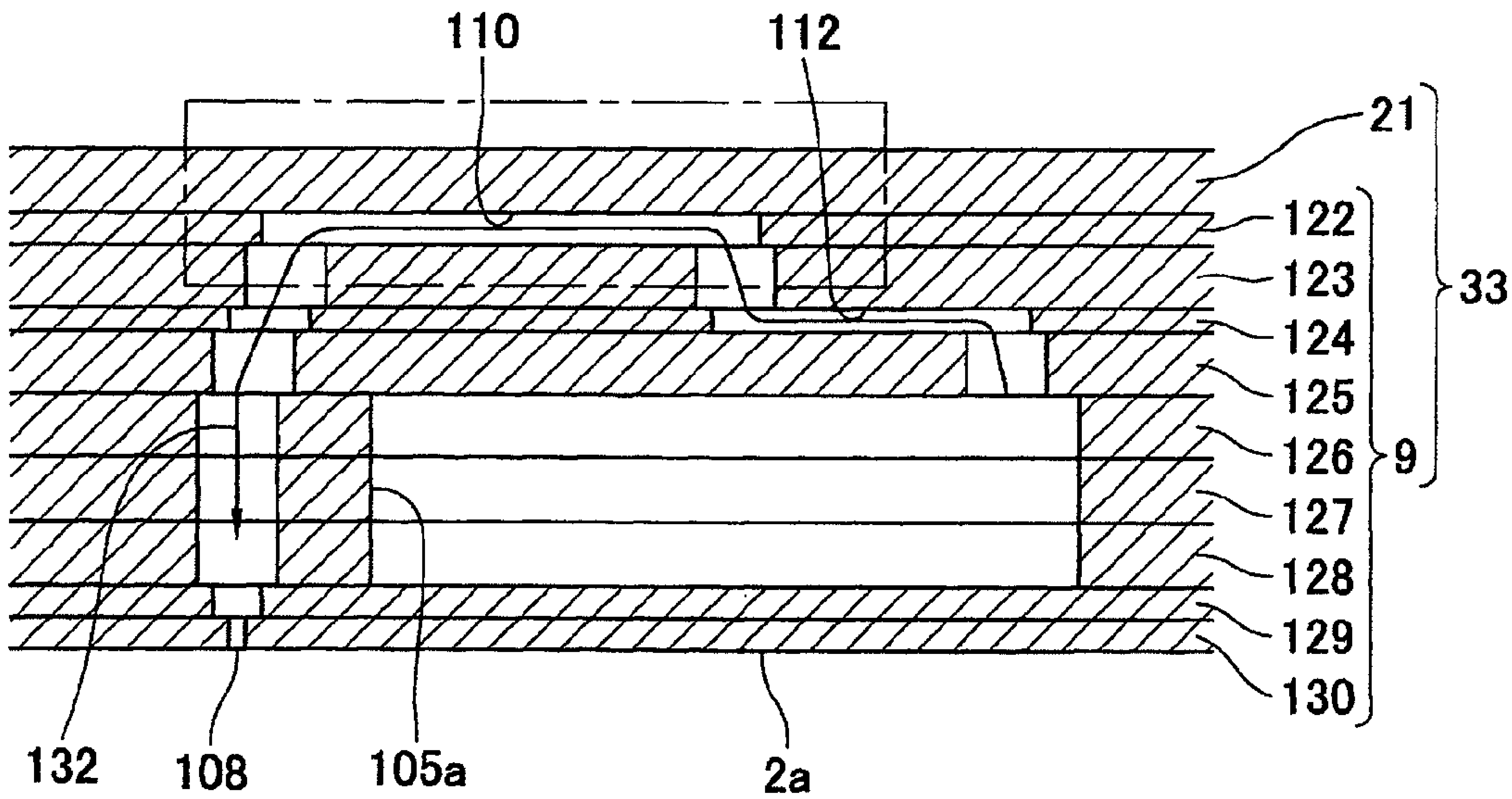


FIG.9


110
112
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129
130
33
9
132
108
105a
2a

FIG.10A

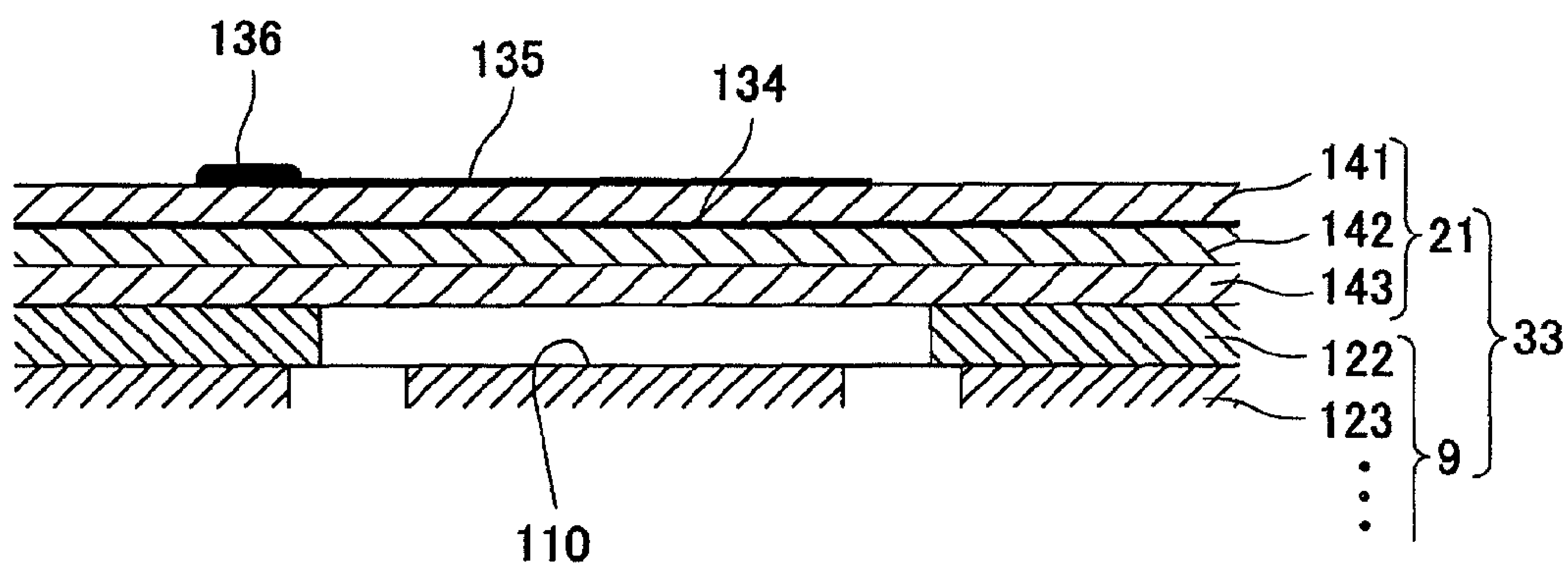
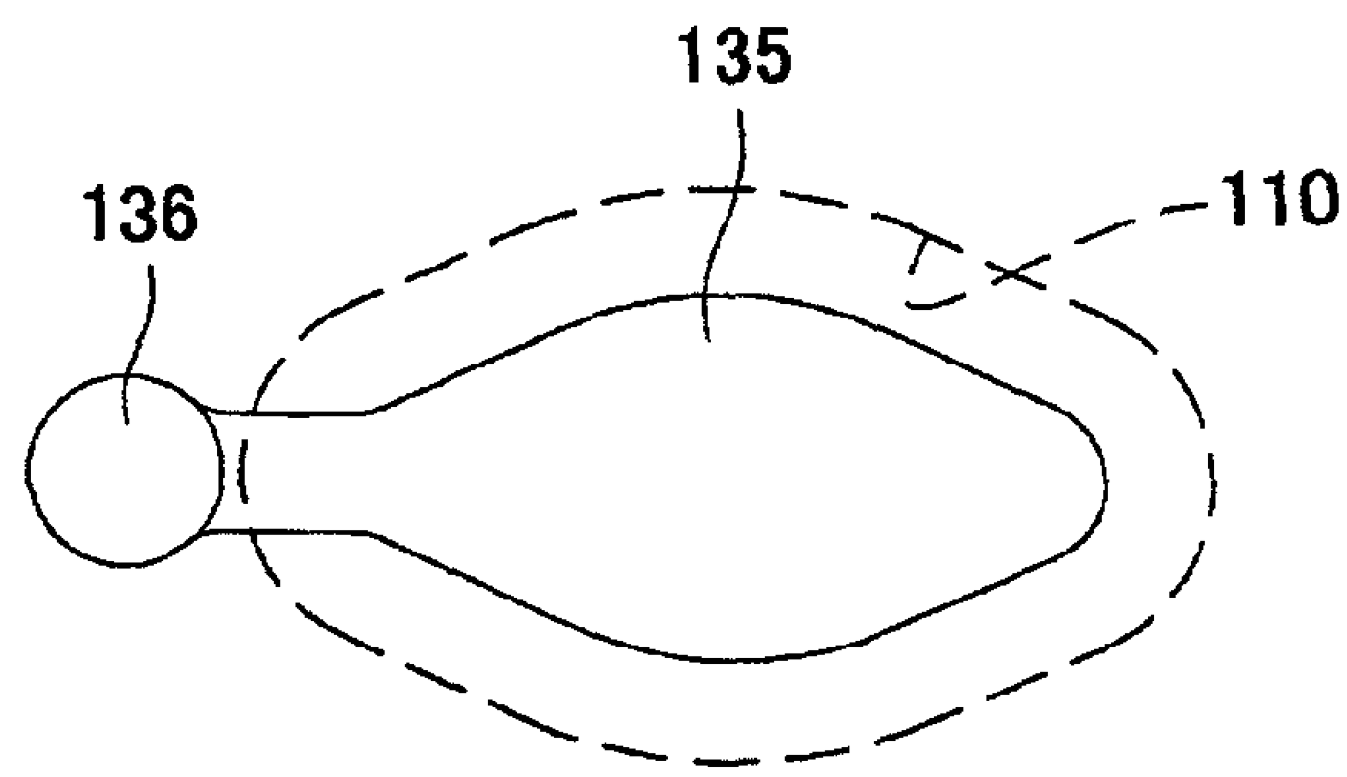


FIG.10B



LIQUID EJECTING HEAD FOR EFFECTIVELY DISCHARGING AIR BUBBLES

CROSS REFERENCE TO RELATED APPLICATION

The present application claims priority from Japanese Patent Application No. 2008-245455, which was filed on Sep. 25, 2008, the disclosure of which is herein incorporated by reference in its entirety.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates in general to a liquid ejecting head for ejecting a liquid therefrom.

2. Description of the Related Art

The following Patent Document 1 discloses an ink-jet head including: a head main body which has an ink ejection surface formed in its lower surface; and a reservoir unit having substantially the same shape, in plan view, as the head main body and temporarily storing ink to be supplied to the head main body. In the disclosed ink-jet head, a filter is disposed in an upper reservoir which is the most upstream region in an ink flow passage formed in the reservoir unit. To the upper reservoir, a discharge passage is connected at a portion of the upper reservoir that is located on the downstream side of the filter. The discharge passage is branched from the upper reservoir and reaches a discharge port provided in the reservoir unit.

Air bubbles staying between the filter and a branch point at which the discharge passage is branched from the upper reservoir (i.e., a connecting point at which the discharge passage is connected to the upper reservoir) are forcibly discharged to an outside of the reservoir unit from the discharge port through the discharge passage, by conducting a pressure purging operation in which ink is supplied to the reservoir unit using a pump connected to an upstream end of the reservoir unit. The air bubbles are thus forcibly discharged, thereby obviating an occurrence of ejection failure and permitting the ink-jet head to recover from the ejection failure.

Patent Document 1: JP-A-2007-268868

SUMMARY OF THE INVENTION

In the ink-jet head disclosed in the above-indicated Patent Document 1, the flow passage connected to a downstream end of the upper reservoir is branched into two passages in each of which five outflow passages are formed. The outflow passages are connected to passages formed in the head main body. The above-described discharge passage is connected to the upper reservoir at the branch point indicated above that is located more upstream than the position which is located on the downstream side of the filter and at which the flow passage is branched into two passages. Accordingly, even though the pressure purging operation is conducted, the air bubbles that can be discharged through the discharge passage are limited to those staying between the filter and the branch point. Therefore, the air bubbles existing in the passages in the reservoir unit that extend from the branch point to the head main body, namely, the air bubbles existing in the substantial part of the passages in the reservoir unit, cannot be discharged through the discharge passage.

The ink-jet head disclosed in the Patent Document 1 indicated above may be modified to have another filter disposed at a boundary between the reservoir unit and the head main body and having a mesh size smaller than that of the filter disposed

in the upper reservoir. In this instance, however, the air bubbles staying between the branch point and the head main body cannot be sufficiently discharged from the nozzles of the head main body by the purging operation in which the output level of the pump is set at a normal level because of a large pressure loss due to the two different kinds of filters. Accordingly, it is needed to set the output level of the pump at a higher level than usual. However, the increase in the output level of the pump involves an increase in the amount of ink to be discarded, causing a disadvantage to users.

A need has arisen for a liquid ejecting head capable of effectively discharging air bubbles while suppressing an amount of a liquid to be discarded in a purging operation where two different kinds of filters are disposed in the liquid ejecting head.

According to one embodiment herein, a liquid ejecting head for ejecting a liquid from a plurality of ejection holes may comprise: a first flow-passage member in which are formed (a) a liquid-supply passage to which the liquid is supplied from an exterior of the liquid ejecting head, (b) a plurality of branch passages connected to the liquid-supply passage, and (c) a plurality of discharge passages each of which is connected to any of the plurality of branch passages and each of which is in communication with an outside of the first flow-passage member;

a second flow-passage member in which are formed (a) at least one common liquid passage each of which is in communication with at least one of the plurality of branch passages and (b) a plurality of individual passages which are provided so as to respectively correspond to the plurality of ejection holes, each of which is connected to any one of the at least one common liquid passage, and which respectively have pressure chambers formed therein, each of the plurality of individual liquid passages introducing the liquid to a corresponding one of the plurality of ejection holes via a corresponding one of the pressure chambers; a first filter disposed in the liquid-supply passage; a plurality of second filters disposed between the plurality of branch passages and the at least one common liquid passage: and at least one energy giving member configured to give ejection energy to the liquid in each of the pressure chambers that are formed respectively in the plurality of individual liquid passages.

In the liquid ejecting head described above wherein the discharge passages are connected to any of the branch passages, the air bubbles staying in the first flow-passage member between the first and second filters, especially, the air bubbles staying between the first filter and inlets of the discharge passages, can be effectively discharged through the discharge passages while suppressing the amount of the liquid to be discarded upon purging in an instance where two different kinds of filters are used.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other objects, features, advantages and technical and industrial significance of the present invention will be better understood by reading the following detailed description of a preferred embodiment of the invention, when considered in connection with the accompanying drawings, in which:

FIG. **1** is a vertical cross sectional view showing an internal structure of an ink-jet printer including an ink-jet head according to one embodiment of the invention;

FIG. **2** is an exploded perspective view of the ink-jet head of FIG. **1**;

FIG. **3** is a plan view of a part of a plurality of plates constituting the ink-jet head of FIG. **1**;

FIG. **4** is a plan view of a part of the plurality of plates constituting the ink-jet head of FIG. **1**;

FIG. **5** is a cross sectional view of a filter support member included in the ink-jet head;

FIG. **6** is a schematic cross sectional view of the ink-jet head in its longitudinal direction;

FIG. **7** is a plan view showing a relationship among a second discharge passage, an outflow passage, and a filter;

FIG. **8** is an enlarged plan view of a part of a flow-passage unit included in the ink-jet head;

FIG. **9** is a cross sectional view taken along line IX-IX in FIG. **8**; and

FIG. **10**A is an enlarged cross sectional view of the actuator unit and FIG. **10**B is a plan view of an individual electrode.

DETAILED DESCRIPTION OF THE EMBODIMENT

Referring to the drawings, there will be explained an embodiment of the present invention.

FIG. **1** shows an internal structure of an ink-jet printer including an ink-jet head as a liquid ejecting head according to one embodiment of the invention. As shown in FIG. **1**, the ink-jet printer generally indicated at **101** in FIG. **1** has a casing **101***a* having a rectangular parallelepiped shape. In the casing **101***a*, there are disposed: four ink-jet heads **1** which respectively eject magenta ink, cyan ink, yellow ink, and black ink; and a sheet conveying mechanism **16**. On the inner surface of the top plate of the casing **101***a*, a control portion **100** for controlling operations of the ink-jet heads **1** and the sheet conveying mechanism **16** is attached. A sheet-supply unit **101***b* is disposed below the sheet conveying mechanism **16**. The sheet-supply unit **101***b* is removably attached to the casing **101***a*. Below the sheet-supply unit **101***b*, an ink tank unit **101***c* is disposed so as to be detachable from the casing **101***a*.

In the ink-jet printer **101**, there is formed a sheet delivery path through which a sheet P is delivered along solid arrows in FIG. **1** from the sheet-supply unit **101***b* toward a sheet receiving recessed portion **15**. The sheet-supply unit **101***b* includes: a sheet tray **11** having a box-like shape opening upward and accommodating a stack of the sheets P; and a sheet-supply roller **12** configured to supply an uppermost one of the sheets P accommodated in the sheet tray **11**. The sheet P supplied from the sheet tray **11** by the sheet-supply roller **12** is delivered to the sheet conveying mechanism **16** while being guided by sheet guides **13***a*, **13***b* and nipped by rollers of a feed roller pair **14**.

The sheet conveying mechanism **16** includes: two belt rollers **6**, **7**; an endless sheet conveyor belt **8** wound around the two rollers **6**, **7** so as to be stretched therebetween; a tension roller **10** which is in contact with the inner circumferential surface of the sheet conveyor belt **8** at the lower half portion of the loop of the sheet conveyor belt **8** while being biased downwardly, thereby applying tension to the sheet conveyor belt **8**; and a platen **18** which is disposed in a region enclosed by the sheet conveyor belt **8**. The platen **18** supports, at a position where the platen **18** is opposed to the ink-jet heads **1**, the sheet conveyor belt **8** so as to prevent the sheet conveyor belt **8** from sagging downward. The belt roller **7** is a drive roller configured to be rotated clockwise in FIG. **1** by a drive force given to its shaft from a sheet delivery motor **19**. The belt roller **6** is a driven roller configured to be rotated clockwise in FIG. **1** by the movement of the sheet conveyor belt **8** in accordance with rotation of the belt roller **7**. The drive force of the sheet delivery motor **19** is transmitted to the belt roller **7** through a plurality of gears.

The outer circumferential surface **8***a* of the sheet conveyor belt **8** is silicone-treated so as to have adhesion property. A nip roller **4** is disposed at a position on the sheet delivery path at which the nip roller **4** faces the belt roller **6** with the sheet conveyor belt **8** interposed therebetween. The nip roller **4** is configured to press the sheet P supplied from the sheet-supply unit **101***b* onto the outer circumferential surface **8***a* of the sheet conveyor belt **8**. The sheet P pressed onto the outer circumferential surface **8***a* of the sheet conveyor belt **8** is conveyed in a sheet conveyance direction, namely, in a sub scanning direction (in the rightward direction in FIG. **1**), while being held on the outer circumferential surface **8***s* of the sheet conveyor belt **8** owing to its adhesion property.

A separation plate **5** is disposed at a position on the sheet delivery path where the separation plate **5** faces the belt roller **7**. The separation plate **5** separates the sheet P held on the outer circumferential surface **8***a* of the sheet conveyor belt **8** therefrom. The separated sheet P is delivered upward while being guided by sheet guides **29***a*, **29***b* and nipped by rollers of each of two feed roller pairs **28**. Subsequently, the sheep P is ejected from an outlet **30** formed at the upper portion of the casing **101***a* to the sheet receiving recessed portion **15** formed on the upper surface of the casing **101***a*.

The four ink-jet heads **1** respectively eject inks of the mutually different colors, i.e., magenta, yellow, cyan, and black. Each ink-jet head **1** has a generally rectangular parallepiped shape having a longer dimension in a main scanning direction that is perpendicular to the sub scanning direction. The dimension of each head **1** as measured in the main scanning direction is larger than the width of the sheet. The four ink-jet heads **1** are arranged side by side in the sheet conveyance direction and immovable in the main scanning direction. That is, the ink-jet printer **101** is a printer of a line type.

The bottom surface of each ink-jet head **1** is made as an ejection surface **2***a* in which are formed a plurality of ejection holes **108** (FIG. **9**) through which the ink is ejected. When the sheet P being conveyed passes right below the four ink-jet heads **1**, the inks of the different colors are ejected from the ejection holes **108** toward the upper surface of the sheet P, whereby an intended color image is formed on the upper surface, i.e., on the print surface, of the sheet P.

The four ink-jet heads **1** are connected respectively to four ink tanks **17** disposed in the ink tank unit **101***c*. The inks of the mutually different four colors are stored in the respective four ink tanks **17**. The inks are supplied from the ink tanks **17** to the respective ink-jet heads **1** via respective tubes.

FIG. **2** is an exploded perspective view of the ink-jet head **1**. As shown in FIG. **2**, the ink-jet head **1** includes: a base plate **31**; a reservoir unit **32** as a first flow-passage member; and a head main body **33** that includes a flow-passage unit **9** as a second flow-passage member. As shown in FIGS. **2**-**4**, the reservoir unit **32** is constituted by: a laminar body **37** including three plates **42**-**44** and a small-plate group **45**; and a filter support member **41** that is fixed to the upper surface of the laminar body **37**. The small-plate group **45** consists of eight inner small plates **45***a* and two outer small plates **45***b*.

Referring to the cross sectional view of FIG. **5**, the filter support member **41** will be explained. The filter support member **41** to which the ink is supplied from the ink tank **17** is formed by integral molding of a resin material. Three cylindrical projections **70***a*, **70***b*, **70***c* project upward from an upper surface **70***f* of the filter support member **41**. A supply inlet **71** is formed in the cylindrical projection **70***a*. To the cylindrical projection **70***a*, a flexible tube is attached, and the ink in the ink tank **17** as an ink supply source is introduced into the filter support member **41** from the supply inlet **71** via the tube. A pump (not shown) for pressure purging is attached to the tube.

There is formed, in the filter support member **41**, an ink flow passage **73** as an upstream region of a liquid-supply passage. The ink flow passage **73** includes: the supply inlet **71** in which an ink inlet opening is formed and which vertically extends; and a supply outlet **72** in which an ink outlet opening is formed and which vertically extends. The ink flow passage **73** includes an intermediate portion **93** between the supply inlet **71** and the supply outlet **72**. In the intermediate portion **93**, there is formed an elongate, rectangular opening **74***a* opening downward.

To the filter support member **41**, there is attached a filter **79** as a first filter in which a plurality of minute through-holes are formed for filtering the ink. The filter **79** divides the intermediate portion **93** into: a first space **74** which is held in communication with the supply inlet **71** and which is defined by the rectangular opening **74***a*; and a second space **75** which is held in communication with the supply outlet **72**. A region of the second space **75** which does not face the filter **79**, i.e., a non-facing region **76**, horizontally extends at a height level that is slightly higher than a height level of a region of the second space **75** which faces the filter **79**. The supply outlet **72** extends from the non-facing region **76** in the vertically downward direction so as to open to a lower surface **70***e* of the filter support member **41**.

The first space **74** has an elongate, rectangular shape. The opening **74***a* is sealed by a damper film **78** as a seal member. The damper film **78** has generally the same shape as the opening **74***a* in plan view. Thus, the damper film **78** cooperates with the filter support member **41** to define the ink flow passage **73**. A peripheral wall **74***b* that defines the opening **74***a* extends downward to a predetermined height level throughout its periphery, so that the damper film **78** fixed to the lower end of the peripheral wall **74***b* extends horizontally.

In the second space **75**, a downward opening **75***a* is defined by a recess. The opening **75***a* faces a part of the damper film **78** that extends from a position on a right side of the center of the damper film **78** to the right-side end of the same **78**. The opening **75***a* has a shape, in plan view, that tapers in both of a direction of the ink flow and a direction opposite to the ink flow direction. The filter **79** has a shape substantially similar to that of the opening **75***a* and has a size in plan view somewhat larger than the opening **75***a*. The filter **79** is fixed in the first space **74** so as to cover the opening **75***a*. In other words, the filter **79** is fixed to the filter support member **41** so as to be opposed to the opening **74***a* and the damper film **78**.

The ink introduced from the supply inlet **71** initially flows substantially horizontally in the first space **74** from the left to the right in FIG. **5**, then reaches the region of the first space facing the filter **79**, and flows upward through the filter **79**. Subsequently, the ink flows into the second space **75** through the filter **79**. In this occasion, foreign substances present in the ink flowed from the first space **74** are caught by the filter **79**, and the ink from which the foreign substances have been removed by the filter **79** flows in the second space **75**. After the ink has flowed in the non-facing region **76** of the second space **75**, the ink flows downward through the supply outlet **72** and is finally discharged into the plate **42**.

The damper film **78** is a flexible resin film. Between the damper film **78** and the upper surface of the plate **42**, there is formed a clearance that allows deflection of the damper film **78** in accordance with vibration of the ink. According to the structure described above, the damper film **78** is deflected in the substantially vertical direction in accordance with the vibration of the ink, whereby the vibration of the ink can be absorbed and damped.

An opening is formed in the upper surface **70***f* of the filter support member **41** to define the non-facing region **76**. The opening is sealed by a film **76***a* having flexibility, and the film **76***a* is deflected in accordance with the vibration of the ink, whereby the vibration of the ink is absorbed and damped. An opening formed in second discharge passages that will be explained below is also covered also by the film **76***a*.

In the filter support member **41**, there is further formed a first discharge passage connecting the first space **74** and an outlet opening of the cylindrical projection **70***b*. The first discharge passage initially extends below the non-facing region **76** in the width direction of the filter support member **41**, then extends in the longitudinal direction of the filter support member **41** after having extended upward to the same height level as the non-facing region **76**, and finally communicates with the cylindrical projection **70***b* on the downstream side of a position at which the first discharge passage comes down to a height level lower than the filter **79**. A region **77** having the same height level as the non-facing region **76** is defined by sealing an opening formed in the upper surface **70***f* of the filter support member **41** with a film **76***b*. The first discharge passage is utilized for discharging air bubbles staying in a portion of the filter support member **41** located on the upstream side of the filter **79**.

In the filter support member **41**, there is further formed an ink flow passage **86** as a downstream region of each of the second discharge passages which has an outlet at the tip of the cylindrical projection **70***c*. The ink flow passage **86** is a flow passage extending between a discharge inlet **82** that extends vertically upward from the lower surface **70***e* of the filter support member **41** and a discharge outlet **81** formed in the cylindrical projection **70***c*. The discharge inlet **82** is connected to a through-hole **42***b* of the plate **42** as described below.

The ink flow passage **86** initially extends from the upper end of the discharge inlet **82**, subsequently extends, in the longitudinal direction of the filter support member **41**, through an upper region **83** having the same height level as the non-facing region **76**, then extends, in the longitudinal direction of the filter support member **41**, through a lower region **84** that is located at a height level close to that of the lower surface **70***e* of the filter support member **41**, and finally extends upward from the end of the lower region **84** so as to be held in communication with the discharge outlet **81** formed in the cylindrical projection **70***c*. The upper region **83** is defined by sealing the upward opening formed in the upper surface **70***f* of the filter support member **41** by the film **76***a*. The lower region **84** is defined by sealing a downward opening formed in the lower surface **70***e* of the filter support member **41** by a horizontally extending damper film **85** as a seal member. The second discharge passages are utilized to discharge air bubbles staying in a portion of the ink-jet head **1** that is located downstream of the filter **79** and upstream of connecting points that will be explained.

Each of the plates of the laminar body **37**, i.e., the plates **42**-**44** and the small-plate group **45**, is formed of a metal material having a higher degree of heat conductivity than the resin material of the filter support member **41**. In the plates of the laminar body **37**, there are formed through-holes and recesses which provide the downstream region of the liquid-supply passage, two branch passages (including eighteen outflow passages), and upstream regions of the respective second discharge passages as described below in detail.

More specifically, two through-holes **42**a, **42**b are formed through the thickness of the plate **42** in the vicinity of the central portion of the same **42**, such that the through-hole **42**a is opposed to the supply outlet **72** formed in the filter support member **41** and the through-hole **42**b is opposed to the discharge inlet **82** formed in the same **41**. The through-hole **42**a that is a part of the downstream region of the liquid-supply passage is connected to the supply inlet **72**, namely, connected to the ink flow passage **73** while the through-hole **42**b that is a part of the upstream region of each of the second discharge passages is connected to the discharge inlet **82**, namely, connected to the ink flow passage **86**.

A through-hole **43**a is formed through the thickness of the plate **43** so as to be opposed to the through-hole **42**a of the plate **42**. The through-hole **43**a is a part of the downstream region of the liquid-supply passage. Further, a recess **43**b as a part of the upstream region of each of the second discharge passages is formed in the plate **43** such that the central portion of the recess **43**b is opposed to the through-hole **42**b of the plate **42** at the central portion of the plate **43**. The recess **43**b is branched into a plurality of narrow passages near respective eighteen through-holes **43**d as will be explained below. The recess **43**b is formed by etching a substantially upper half portion of the plate **43** in its thickness direction.

In addition to the through-hole **43**a and the recess **43**b, the eighteen through-holes **43**d are formed through the thickness of the plate **43** so as to be located within the recess **43**b. More specifically, the eighteen through-holes **43**d each as a part of the upstream region of the corresponding second discharge passage are located so as to be contiguous to the periphery of the recess **43**b and are arranged, along the longitudinal direction of the plate **43**, in two rows each consisting of nine through-holes **43**d. The nine through-holes **43**d in each of the two rows are disposed such that eight through-holes **43**d except for the outermost one of the through-holes **43**d form four pairs. Each pair consists of two through-holes **43**d that are located adjacent to each other. Further, the eighteen through-holes **43**d are disposed so as to have point symmetry with respect to the center (the central portion **43**c) of the plate **43**.

An elongate recess **44**a is formed in the plate **44** so as to extend from one of longitudinal end portions of the plate **44** to the other of the longitudinal end portions of the same **44**. The central portion of the recess **44**a is opposed to the through-hole **43**a of the plate **43**. The recess **44**a is formed by etching a substantially upper half portion of the plate **44** in its thickness direction. As will be explained, the recess **44**a provides upstream regions of the respective two branched passages.

In addition to the recess **44**a, eighteen through-holes **44**b are formed through the thickness of the plate **44** in the vertical direction so as to be located within the recess **44**a. Each through-hole **44**b has a linear or straight shape that extends in a direction in which the ink flows into a corresponding filter **106** as a second filter (FIG. **6**) that will be explained. The eighteen through-holes **44**b are located so as to be contiguous to the periphery of the recess **44**a and are arranged, along the longitudinal direction of the plate **44**, in two rows each consisting of nine through-holes **44**b. Each through-hole **44**b is opposed to a corresponding one of the through-holes **43**d of the plate **43**.

In each of eight inner small plates **45**a in the small-plate group **45**, there are formed two through-holes **47**a which are to be opposed to corresponding two adjacent through-holes **44**b of the plate **44**. In each of two outer small plates **45**b between which the eight inner small plates **45**a are disposed, one through-hole **47**b is formed so as to be opposed to a corresponding one of the outermost through-holes **44**b of the plate **44**. Each of the through-holes **47**a, **47**b has the same diameter as the through-holes **44**b.

In the present embodiment, the ink flow passage **73** formed in the filter support member **41** and the through-hole **42**a and the through-hole **43**a respectively formed in the plates **42** and the plate **43** are held in communication with each other so as to constitute the liquid-supply passage. The recess **44**a formed in the plate **44** constitutes the upstream regions of the respective two branched passages. Further, the through-holes **44**b formed in the plate **44** and the through-holes **47**a, **47**b formed in the small-plate group **45** are held in communication with each other to constitute the outflow passages. More specifically, each outflow passage is constituted by a combination of the through-hole **44**b formed in the plate **44** and the through-hole **47**a formed in a corresponding inner small plate **45**a or the through-hole **47**b formed in a corresponding outer small plate **45**b. Each outflow passage is connected to a corresponding manifold **105** in the flow-passage unit **9** via a corresponding ink supply hole **105**b that will be described.

Further, the through-holes **43**d and the recess **43**b formed in the plate **43**, the through-hole **42**b formed in the plate **42**, and the ink flow passage **86** formed in the filter support member **41** are held in communication with each other so as to constitute the eighteen branched second discharge passages (as a plurality of discharge passages). The second discharge passages take the form of eighteen narrow passages at the level of the through-holes **43**d. The eighteen narrow passages gradually decrease in number toward the central portion **43**c of the plate **43**, and finally merge with each other into one at the central portion **43**c as a merge point. As a discharge port of the second discharge passages, only the above-described outlet formed at the tip of the cylindrical projection **70**c exists in the reservoir unit **32**. Because the only one discharge port of the second discharge passages exists, it is possible to simplify the connecting structure with respect to the reservoir unit **32**. To the discharge port, one end of a tube (not shown) is connected, whereby the discharge port is connected to an atmosphere release opening provided at the other end of the tube, via an open/close valve attached to the tube.

As shown in FIG. **4**, the head main body **33** includes the flow-passage unit **9**, ten filters **106**, and eight actuator units **21**. The filters **106** and the actuator units **21** are fixed to the upper surface of the flow-passage unit **9**. Each filter **106** is provided for a corresponding one of the ten small plates **45**a, **45**b, and covers one or two ink supply holes **105**b.

Each of the eight actuator units **21** includes a plurality of piezoelectric actuators for giving ejection energy to the ink in respective pressure chambers **110** (FIG. **9**). A COF **51** which is a flat flexible substrate is bonded to the upper surface of each actuator unit **21**, as shown in FIG. **2**. On each COF **51**, a driver IC **52** for generating drive signals to be supplied to the corresponding actuator unit **21** is mounted. The filter support member **41**, the laminar body **37**, and the flow-passage unit **9** are stacked on one another in a direction in which the ink flows from the eighteen outflow passages to the manifolds **105**, so as to provide a laminated structure.

A plurality of electronic components are disposed on the base plate **31** of the head **1**. The COFs **51** are connected to the electronic components via connectors **31**a attached to the base plate **31**. The electronic components disposed on the base plate **31** are connected to the control portion **100** via wires not shown.

FIG. **6** is a schematic cross sectional view of the head **1** in its longitudinal direction, in which the base plate **31** is not illustrated. In FIG. **6**, the aspect ratio of each component is largely changed in order that passages can be easily visible. As shown in FIG. **6**, the ink that has flowed from the ink flow passage **73** down to the recess **44***a* via the through-holes **42***a*, **43***a* flows in the recess **44***a* in mutually opposite directions toward the respective longitudinal or outer end portions of the plate **44**. That is, two portions of the recess **44***a* that extend from a central portion **44***c* of the recess **44***a* toward the respective longitudinal ends of the plate **44**, namely, a right half portion of the recess **44***a* and a left half portion of recess **44***a* as seen in FIG. **6**, function as the two branched passages which are branched from the liquid-supply passage.

The ink that has flowed in the recess **44***a* in the mutually opposite directions flows into the flow-passage unit **9** via the eighteen outflow passages formed of the through-holes **44***b* of the plate **44** and the through-holes **47***a*, **47***b* of the plate **45**.

In the present embodiment, the second discharge passages are connected to the branched passages at respective connecting points (at the upper ends of the respective through-holes **44***b*) which are located downstream of the filter **79** and downstream of the central portion **44***c* of the recess **44***a* at which the liquid-supply passage is branched into the two branched passages. Accordingly, a substantial part of the air bubbles staying in the head **1** can be effectively discharged through the second discharge passages in the pressure purging operation.

In the present embodiment, nine outflow passages (through-holes **44***b*, **47***a*, **47***b*) are formed in each of the two branched passages. In other words, in the present embodiment, a plurality of outflow passages are divided into a plurality of groups so as to correspond to the plurality of branch passages, and a part of the plurality of outflow passages that belongs to each of the plurality of groups forms portions of a corresponding one of the plurality of branch passages. Each of the two branched passages is connected at the nine outflow passages to corresponding manifolds **105** each as a common liquid passage formed in the flow-passage unit **9**. Further, each filter **106** is disposed between the corresponding through-holes **47***a* or through-hole **47***b* and the corresponding manifold **105**. Moreover, the second discharge passages are formed so as to correspond to the respective outflow passages. According to the arrangement, the air bubbles staying in the reservoir unit **32**, especially in the laminar body **37**, can be effectively discharged.

Each outflow passage has a linear or straight shape extending in the direction in which the ink flows into a corresponding one of the filters **106**. In other words, each outflow passage linearly extends in a direction parallel to the direction in which the ink flows into the filter **160**. Each of the second discharge passages is connected to the upper or upstream end of a corresponding one of the outflow passages having the linear or straight shape and has a linear region (the through-hole **43***d*) that extends from a connecting point with the corresponding outflow passage in a direction opposite to a direction in which the corresponding outflow passage extends. In the present embodiment, the connecting point of each second discharge passage with the corresponding outflow passage coincides with the above-indicated connecting point of each second discharge passage with the corresponding branch passage. According to the arrangement, one outflow passage composed of the through-holes **44***b*, **47***a* or **47***b*, and the linear region (the through-hole **43***d*) of one second discharge passage that corresponds to that one outflow passage are arranged in a straight line, whereby the air bubbles staying in the reservoir unit **32**, especially in the laminar body **37**, can be effectively discharged.

In the present embodiment, the through-hole **43***d* as the linear region of each second discharge passage is formed as a first penetrating passage that penetrates through the plate **43**. Further, each outflow passage of the branch passages is formed as a second penetrating passage that penetrates through the plates **44** and the plate **45***a* or **45***b*. As shown in FIG. **7**, the size (the diameter) of the first penetrating passage (the through-hole **43***d*) is larger than that of the second penetrating passage (the through-holes **44***b*, **47***a*, **47***b*). Further, the second penetrating passage is located within the first penetrating passage when viewed in a direction of lamination of the plates of the reservoir unit **32**, and the filter **106** is attached to the plate **45***a* or **45***b* such that the filter **106** is exposed to the bottom of the second penetrating passage, namely, the filter **106** is disposed at one end of the second penetrating passage. Accordingly, the air bubbles staying on the filter **106** can easily flow upward to the corresponding second discharge passage.

As explained above, the reservoir unit **32** has a laminated structure including the plates **41**-**44** and the small-plate group **45**. Respective regions of the eighteen second discharge passages except: the downstream regions thereof located on the downstream side of the central portion **43***c* of the plate **43** (i.e., the merge point); and the linear regions thereof (the through-holes **43***d*) are provided by the recess **43***b* formed in the plate **43**. In other words, a region of each of the second discharged passages except: its downstream region located on the downstream side of the central portion **43***c* of the plate **43** (i.e., the merge point); and its linear region (the through-hole **43***d*) is defined within the thickness of the plate **43**. In the present embodiment, the downstream regions of the respective eighteen second discharge passages are common to each other. Respective regions of the two branch passages except regions thereof corresponding to the outflow passages (the through-holes **44***b*, **47***a*, **47***b*) are provided by the recess **44***a* formed in the plate **44**. In other words, a region of each branch passage except regions thereof corresponding to the outflow passages formed therein is defined within the thickness of the plate **44**. According to the arrangement, the second discharge passages and the branch passages are provided by a simple structure with a relatively small number of the plates.

As apparent from FIGS. **3** and **4**, a region of each of the eighteen second discharge passages except its linear region (the through-hole **43***d*) and a region of each of the two branch passages except regions thereof corresponding to the outflow passages formed therein at least partially overlap each other when viewed in the direction of lamination of the plates of the reservoir unit **32**. The arrangement reduces the area of the head **1** when viewed from the top.

The eighteen second discharge passages are disposed so as to have point symmetry with respect to the central portion **43***c* of the plate **43** as the merge point, in the plane perpendicular to the ink flow direction into the filters **106**. In other words, the second discharge passages are disposed so as to have point symmetry with respect to the central portion **43***c* of the plate **43** when viewed in the direction parallel to the ink flow direction into the filters **106**. The arrangement reduces a difference among the amounts of the air bubbles to be discharged through the respective second discharge passages.

In the present embodiment, the eighteen second discharge passages have mutually the same resistance against a flow of the ink flowing therethrough from the connecting portions located at the upstream ends of the through-holes **44***b* to the outlet at the tip of the cylindrical projection **70***c*. The arrangement reduces a difference among the amounts of the air bubbles to be discharged through the respective second discharge passages.

Referring next to FIGS. **8**, **9**, **10**A, and **10**B, the head main body **33** will be explained in detail. FIG. **8** is a plan view showing a part of two adjacent actuator units **21**. FIG. **9** is a partial cross sectional view of the flow-passage unit **9** along line IX-IX in FIG. **8**. FIG. **10**A is an enlarged cross sectional view of an area enclosed by the dashed line in FIG. **9** and FIG. **10**B is a plan view of an individual electrode. In FIG. **8**, apertures **112** that should be indicated by a broken line are indicated by a solid line for easier understanding.

As shown in FIG. **8**, a plurality of pressure chambers **110** each having a generally rhombic shape are regularly disposed in a matrix on the upper surface of the flow-passage unit **9**. Each actuator unit **21** includes a plurality of individual electrodes **135** (FIG. **10**A) disposed so as to be respectively opposed to the plurality of pressure chambers **110** formed in the flow-passage unit **9**. The actuator unit **21** has a function of selectively giving ejection energy to the ink in the pressure chambers **110**.

The ink supply holes **105***b* (FIG. **4**) are open to the upper surface of the flow-passage unit **9** so as to respectively correspond to the eighteen outflow passages of the reservoir unit **32**. The ink supply holes **105***b* are covered with the corresponding filters **106** each having a smaller mesh size than the filter **79**. The foreign substances existing in the ink that has passed through the outflow passages are caught by the filters **106**, and the ink from which the foreign substances have been removed flows into the flow-passage unit **9**. In the flow-passage unit **9**, there are formed: a plurality of manifolds **105** each extending from a corresponding one of the ink supply holes **105***b*; and a plurality of sub manifolds **105***a*, each as a common liquid passage, which are branched from corresponding manifolds **105**. On the lower surface of the flow-passage unit **9**, the ejection surfaces **2***a* are arranged in each of which a plurality of ejection holes **108**, each as a nozzle opening, are regularly arranged in matrix.

As shown in FIG. **9**, the flow-passage unit **9** is constituted by nine metal plates including a cavity plate **122**, a base plate **123**, an aperture plate **124**, a supply plate **125**, three manifold plates **126**, **127**, **128**, a cover plate **129**, and a nozzle plate **130**, which are arranged in this order from the top of the flow-passage unit **9**. Each of the nine plates **122-130** has a rectangular shape in plan view which is long in the main scanning direction.

The nine plates **122-130** are positioned with and stacked on each other, whereby a plurality of individual ink passages **132** as a plurality of individual liquid passages are defined in the flow-passage unit **9** each of which extends from an outlet of a corresponding one of the sub manifolds **105***a* to a corresponding one of the ejection holes **108** via a corresponding one of the pressure chambers **110**. The ink which has supplied from the reservoir unit **32** to the flow-passage unit **9** via the ink supply holes **105***b* flows into the sub manifolds **105***a* from the manifolds **105**. The ink in the sub manifolds **105***a* flows into the individual ink passages **132** and reaches nozzle ejection holes **108** via the apertures **112** each functioning as an orifice and the pressure chambers **110**.

The actuator unit **21** will be explained. As shown in FIG. **4**, the eight actuator units **21** each having a trapezoidal shape in plan view are arranged in a zigzag fashion in the longitudinal direction of the flow-passage unit **9** so as to avoid the ink supply holes **105***b*. Parallel facing sides (short and long sides) of each actuator unit **21** are parallel to the longitudinal direction of the flow-passage unit **9**, and oblique sides of neighboring two actuator units **21** partially overlap as viewed in the longitudinal direction of the flow-passage unit **9**, namely, in the main scanning direction, as shown in FIG. **8**.

As shown in FIG. **10**A, each actuator unit **21** includes three piezoelectric layers **141-143** formed of a ceramic material of lead zirconate titanate (PZT) having ferroelectricity. The individual electrodes **135** are formed on respective regions of the uppermost piezoelectric layer **141** that correspond to the pressure chambers **110**. A common electrode **134** is provided on an interface between the uppermost piezoelectric layer **141** and the piezoelectric layer **142** located under the layer **141**. As shown in FIG. **10**B, each individual electrode **135** has a generally rhombic shape in plan view similar to the pressure chamber **110**. One acute end portion of the individual electrode **135** extends beyond the pressure chamber **110**, and a circular land **136** is formed at the acute end portion for electrical connection with the individual electrode **135**. In addition to the lands **136** for the individual electrodes **135**, a land for the common electrode **134** is formed on the upper surface of the piezoelectric layer **141**. The land for the common electrode **134** is connected to the common electrode **134** via the conductive material in through-holes.

The common electrode **134** is kept at a ground potential as a basic potential given by the COF **51**. The individual electrodes **135** are electrically connected to terminals of the driver IC **52** via the respective lands **136** and respective internal wires of the COF **51**. A drive signal for driving the actuator unit **21** is supplied from the driver IC **52** to the individual electrodes **135** independently of each other. Accordingly, respective portions in the actuator unit **21** sandwiched by and between the individual electrodes **135** and the pressure chambers **110** function as individual actuators which are independent of each other. That is, a plurality of actuators, each as an energy giving member, are provided in the actuator unit **21** in the same number as the pressure chambers **110**.

There will be next explained a method of driving each actuator unit **21** to permit ink droplets to be ejected from the nozzles. The piezoelectric layer **141** is polarized in its thickness direction. When an electric field is applied to the piezoelectric layer **141** in the polarization direction with one individual electrode **135** kept at a potential different from that of the common electrode **134**, a portion of the piezoelectric layer **141** to which the electric field is applied functions as an active portion that undergoes strain owing to a piezoelectric effect. The active portion expands in a direction of thickness of the layer **141** and contracts in a direction parallel to the plane of the layer **141** (i.e., in the plane direction) when the electric field and the polarization are in the same direction. In this instance, the amount of deformation of the active portion upon expansion and contraction is larger in the plane direction than in the thickness direction. In the actuator unit **21**, the uppermost one **141** of the three piezoelectric layers that is the most distant from the pressure chambers **110** is an active layer including the active portions while the lower two piezoelectric layers **142**, **143** nearer to the pressure chambers **10** are non-active layers. As shown in FIG. **10**A, the piezoelectric layer **143** is fixed to the upper surface of the cavity plate **122** that defines the pressure chambers **110**. Accordingly, when there is generated a difference in strain in the plane direction between the portion of the piezoelectric layer **141** to which the electric field is applied and the piezoelectric layers **142**, **143** located under the layer **141**, the entirety of the piezoelectric layers **141-143** deforms into a convex shape that protrudes toward the pressure chamber **110** (unimorph deformation). Accordingly, the pressure (ejection energy) is given to the ink in the pressure chamber **110**, so that there is generated a pressure wave in the pressure chamber **110**. The generated pressure chamber propagates from the pressure chamber **110** to the ejection hole **108** of the corresponding nozzle, whereby the ink droplets are ejected from the ejection hole **108**.

Unlike the discharge passage of the ink-jet head disclosed in the above-indicated Patent Document 1, the second discharge passages in the ink-jet head **1** according to the illustrated embodiment are connected to the branch passages at the respective connecting points (at the upper ends of the respective through-holes **44***b*) which are located downstream of the filter **79** and downstream of the central portion **44***c* of the recess **44***a* at which the liquid-supply passage is branched into the two branch passages. Accordingly, a substantial part of the air bubbles staying in the head **1** can be effectively discharged through the second discharge passages in the pressure purging operation. On this occasion, there is not disposed, in the second discharge passages, any component that causes a large pressure loss such as a filter whose mesh size is smaller than that of the filter **79**, it is possible to reduce the pressure loss generated upon discharging of the air bubbles through the second discharge passages. Accordingly, the air bubbles can be sufficiently discharged simply by conducting the purging operation in which the output level of the pump is set at a normal level. Hence, the amount of ink to be discarded by the purging operation does not increase, thereby obviating a disadvantage to the user. Further, the air bubbles can be effectively discharged through the second discharge passages, thereby reducing occurrence of deterioration in the printing performance which would be otherwise caused due to gradual growth of the air bubbles. Accordingly, it is hardly required to replace the ink-jet heads **1**.

It is to be understood that the invention is not limited to the details of the illustrated embodiment, but may be embodied with various changes and modifications, which may occur to those skilled in the art, without departing from the spirit and scope of the invention defined in the attached claims. In the illustrated embodiment, the eighteen second discharge passages are connected to the upstream ends of the respective through-holes **44***b*. Instead, two second discharge passages may be connected to the recess **44***a* on the opposite sides (the left side and the right side) of the central portion **44***c* of the recess **44***a*. While the second discharge passages are provided for the respective eighteen outflow passages in the illustrated embodiment, the second discharge passages may be provided for only a part of the eighteen outflow passages. In this instance, at least one second discharge passage may be provided for each of the nine outflow passages that are located on the left or right side of the central portion **44***c* of the recess **44**.

In the illustrated embodiment, the eighteen second discharge passages merge with each other to become one passage for which only one discharge port is provided. The discharge port may be provided for each of the eighteen second discharge passages. Alternatively, the eighteen second discharge passages may merge with each other such that two or more discharge ports are provided. In the illustrated embodiment, one recess is utilized as a part of each of the second discharge passages or as a part of each of the branch passages. Each second discharge passage or each branch passage may be constituted by only a through-hole without using the recess.

In the illustrated embodiment, the linear region of each second discharge passage is formed by only the through-hole **43***d* formed in the single plate **43**. The linear region may extend through two or more of the plates. While each outflow passage in the illustrated embodiment has a structure in which the through-hole **44***b* of the plate **44** and the through-hole **47***a* or **47***b* of the small-plate group **45** are connected to each other, each outflow passage may be formed by only a through-hole formed in one plate.

Only one common liquid passage may be formed in the flow-passage unit. The passage structure in the head is not limited to that in the illustrated embodiment, but may be otherwise modified. The energy giving member is not limited to the one utilizing the piezoelectric body, but the one of thermal type may be utilized.

It is to be understood that the principle of the invention may be applicable not only to the head for a line printer as in the illustrated embodiment, but also to a head for a serial printer, and further to a head for ejecting a liquid other than the ink.

What is claimed is:

1. A liquid ejecting head for ejecting a liquid from a plurality of ejection holes, comprising:

a first flow-passage member in which are formed (a) a liquid-supply passage to which the liquid is supplied from an exterior of the liquid ejecting head, (b) a plurality of branch passages connected to the liquid-supply passage, and (c) a plurality of discharge passages each of which is connected to any of the plurality of branch passages and each of which is in communication with an outside of the first flow-passage member;

a second flow-passage member in which are formed (a) at least one common liquid passage each of which is in communication with at least one of the plurality of branch passages and (b) a plurality of individual passages which are provided so as to respectively correspond to the plurality of ejection holes, each of which is connected to any one of the at least one common liquid passage, and which respectively have pressure chambers formed therein, each of the plurality of individual liquid passages introducing the liquid to a corresponding one of the plurality of ejection holes via a corresponding one of the pressure chambers;

a first filter disposed in the liquid-supply passage;

a plurality of second filters disposed between the plurality of branch passages and the at least one common liquid passage; and

at least one energy giving member configured to give ejection energy to the liquid in each of the pressure chambers that are formed respectively in the plurality of individual liquid passages,

wherein each of the plurality of discharge passages is connected to one of the plurality of branch passages at a downstream side of the first filter.

2. The liquid ejecting head according to claim **1**,

wherein a plurality of outflow passages are formed in the first flow-passage member, through each of which the liquid is introduced into any one of the at least one common liquid passage and which are divided into a plurality of groups so as to correspond to the plurality of branch passages, a part of the plurality of outflow passages that belongs to each of the plurality of groups forms portions of a corresponding one of the plurality of branch passages, and

wherein each of the at least one common liquid passage is connected to at least one of the plurality of outflow passages.

3. The liquid ejecting head according to claim **2**, wherein the plurality of second filters are disposed between the plurality of outflow passages and the at least one common liquid passage.

4. The liquid ejecting head according to claim **2**, wherein each of the plurality of outflow passages linearly extends in a direction parallel to a direction in which the liquid flows into each of the plurality of second filters.

5. The liquid ejecting head according to claim **4**, wherein the first flow-passage member has a laminar structure composed of a plurality of plates, and

wherein each of the plurality of outflow passages is formed as a penetrating passage that penetrates through at least one of the plurality of plates.

6. The liquid ejecting head according to claim **2**, wherein the plurality of discharge passages are formed so as to respectively correspond to the plurality of outflow passages.

7. The liquid ejecting head according to claim **6**, wherein each of the plurality of discharge passages is connected to any one of the plurality of branch passages at a connecting point that is located at an upstream end of a corresponding one of the plurality of outflow passages.

8. The liquid ejecting head according to claim **7**, wherein each of the plurality of outflow passages linearly extends in a direction parallel to a direction in which the liquid flows into each of the plurality of second filters.

9. The liquid ejecting head according to claim **8**, wherein each of the plurality of discharge passages has a linear region that linearly extends from the connecting point in a direction opposite to the direction in which a corresponding one of the plurality of outflow passages extends.

10. The liquid ejecting head according to claim **9**,
wherein the first flow-passage member has a laminar structure composed of a plurality of plates, and
wherein the linear region of each of the plurality of discharge passages is formed as a penetrating passage that penetrates through at least one of the plurality of plates.

11. The liquid ejecting head according to claim **1**, wherein the plurality of discharge passages have mutually the same resistance against a flow of the liquid flowing therethrough.

12. The liquid ejecting head according to claim **1**, wherein the plurality of discharge passages merge with each other at a merge point in the first flow-passage member, and one discharge port is formed in the first flow-passage member so as to allow each of the plurality of discharge passages to communicate with the exterior.

13. The liquid ejecting head according to claim **12**, wherein the plurality of discharge passages are disposed so as to have point symmetry with respect to the merge point when viewed in a direction parallel to a direction in which the liquid flows into each of the plurality of second filters.

14. The liquid ejecting head according to claim **12**,
wherein a plurality of outflow passages are formed in the first flow-passage member, through each of which the liquid is introduced into any one of the at least one common liquid passage and which are divided into a plurality of groups so as to correspond to the plurality of branch passages, a part of the plurality of outflow passages that belongs to each of the plurality of groups forms portions of a corresponding one of the plurality of branch passages,
wherein each of the at least one common liquid passage is connected to at least one of the plurality of outflow passages,
wherein each of the plurality of outflow passages linearly extends in a direction parallel to a direction in which the liquid flows into each of the plurality of second filters,
wherein the plurality of discharge passages are formed so as to respectively correspond to the plurality of outflow passages,
wherein each of the plurality of discharge passages is connected to any one of the plurality of branch passages at a connecting point that is located at an upstream end of a corresponding one of the plurality of outflow passages and each of the plurality of discharge passages has a linear region that linearly extends from the connecting point in a direction opposite to the direction in which a corresponding one of the plurality of outflow passages extends,
wherein the first flow-passage member has a laminar structure composed of a plurality of plates,
wherein a region of each of the plurality of discharge passages except (a) a downstream region thereof that is located on a downstream side of the merge point and (b) the linear region thereof is defined within a thickness of one of the plurality of plates, and
wherein a region of each of the plurality of branch passages except regions thereof corresponding to the part of the plurality of outflow passages that forms the portions of said each of the plurality of branch passages is defined within a thickness of another one of the plurality of plates that is different from the one of the plurality of plates.

15. The liquid ejecting head according to claim **14**,
wherein the linear region of each of the plurality of discharge passages is formed as a first penetrating passage that penetrates through at least one of the plurality of plates, and
wherein each of the plurality of outflow passages is formed as a second penetrating passage that penetrates through at least another one of the plurality of plates that is different from the at least one of the plurality of plates.

16. The liquid ejecting head according to claim **15**,
wherein the first penetrating passage has a size larger than that of the second penetrating passage, and
wherein the second penetrating passage is located within the first penetrating passage when viewed in a direction of lamination of the plurality of plates.

17. The liquid ejecting head according to claim **16**, wherein each of the plurality of second filters is disposed at one end of a corresponding one of the second penetrating passage.

18. The liquid ejecting head according to claim **14**, wherein a region of each of the plurality of discharge passages except the linear region thereof and a region of each of the plurality of branch passages except regions thereof corresponding to the part of the plurality of outflow passages that forms the portions of said each of the plurality of branch passages at least partially overlap when viewed in a direction of lamination of the plurality of plates.

19. The liquid ejecting head according to claim **1**, wherein each of the plurality of discharge passages is connected to one of the plurality of branch passages at a connecting point positioned downstream from where the plurality of branch passages are connected to the liquid-supply passage.

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